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Effects of air exposure on mortality and growth of undersized pikeperch, *Sander lucioperca*, at low water temperatures with implications for catch-and-release fishing

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Abstract As undersized fish have to be released after capture in most recreational fisheries, the potential mortality associated with this practice is of interest to managers and anglers. The objective of this study was to assess the effects of air exposure on mortality and growth in pikeperch, *Sander lucioperca* (L.), < 500 mm (total length) at low water temperatures (around 10 °C). Fish were exhaustively exercised by manual chasing for 120 s, exposed to air for 0, 60, 120 or 240 s, and afterwards stocked into two ponds to measure mortality and growth rates. Neither mortality nor growth was statistically significantly different among different durations of air exposure. However, mortality was the lowest in both ponds for fish with no air exposure, which suggested that air exposure adversely affected survival. Mortality was inversely related to length and body mass of pikeperch in one of the two ponds. From a management perspective, it is suggested to avoid air exposure in angled pikeperch that are to be released.

KEYWORDS: air exposure, exhaustive exercise, minimum size limit, recreational fisheries, zander.

Introduction

Survival rates of caught and released fish are of interest to fisheries researchers, managers and anglers because of the large number of fish released voluntarily or due to harvest regulations, such as minimum size limits or daily bag limits (Arlinghaus, Mehner & Cowx 2002; Cooke & Cowx 2004; Bartholomew & Bohnsack 2005). Immediate and post-release mortality have historically been measured to evaluate the success of catch-and-release (C&R) recreational angling (Muoneke & Childress 1994). More recently, sublethal impacts, such as physiological disturbances, behavioural alterations and growth impairments have been recognised as additional effects of C&R (Wydoski 1977; Cooke, Schreer, Dunmall & Philipp 2002a; Cooke & Suski 2005). The pikeperch, *Sander lucioperca* (L.), is an important species sought by anglers throughout Europe (Raat 1991; Arlinghaus & Mehner 2004) and is commonly managed with minimum size limits. Therefore, information about the effects of capture and handling on sublegal pikeperch is important for effective management of this species.

In a typical angling event, exhaustive exercise occurs during the fight of the hooked fish, which is then followed by a brief period of air exposure when anglers remove hooks and possibly additionally handle the fish to weigh, measure or photograph it prior to the release. While out of water the gill lamellae can collapse and inhibit gas exchange (Ferguson & Tufts 1992). This procedure results in substantial physiological disturbance, and longer air exposure tends to result in larger adverse physiological impacts and longer recovery periods (Ferguson & Tufts 1992; Mitton & McDonald 1994; Cooke, Philipp, Dunmall & Schreer 2001; Cooke *et al.* 2002a; Cooke, Schreer, Wahl & Philipp 2002b;

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Davis & Parker 2004; Schreer, Resch, Gately & Cooke 2005). Most studies on air exposure have focused on short-term physiological changes associated with blood chemistry or metabolism, but effects on mortality or growth have not been measured to the same extent. Considering the prevalence of mandatory release of undersized (i.e. smaller than the minimum size limit) pikeperch, it is important to know if air exposure affects not only survival but also growth of released fish. The objective of this study was to investigate the effect of exhaustive exercise and varying air exposure durations on mortality and post-release growth of undersized pikeperch. Based on previous research by Ferguson & Tufts (1992) air exposure was expected to increase mortality in pikeperch.

Materials and methods

Study animals and rearing protocol

Hatchery-reared, age-2 pikeperch (200–400 mm total length, $n = 126$) were stocked into an outdoor flow-through concrete raceway (9 m long × 3 m wide × 0.7 m deep) maintained at a water temperature of 14 °C. Prior to stocking, all fish were marked with individually numbered T-bar anchor tags (Floy Manufacturing Inc.) at the posterior insertion of the dorsal fin. The raceway was supplied with prey fish (roach, *Rutilus rutilus* (L.), rudd, *Scardinius erythrophthalmus* (L.) and perch, *Perca fluviatilis* (L.), in the pikeperch's preferred prey size of 40–100 mm (Mittelbach & Persson 1998). Due to tagging, handling, cannibalism and acclimatisation stress to the new environment, a total of 17.7% losses ($n = 31$) occurred during a 3-week acclimatisation period in the outside holding raceway.

Angling simulation

To eliminate confounding variables, such as hooking injury, gear, fish size and water temperature, the experiment was conducted by simulating an angling event at different air exposure durations at cool water temperatures with similar-sized fish (Table 1). Sublegal-size pikeperch (fish smaller than the typical minimum size limit of 450–500 mm in Germany) were used because of the difficulties rationalising a C&R study with legal-size fish in the German institutional environment (Arlinghaus 2007) and because these size classes experience the highest likelihood of release in most recreational fisheries.

To begin the trial, water level in the raceway was lowered and each fish was carefully netted with a knotless landing net. Fish were individually transferred into a 400-L fibreglass tank. To simulate exhaustive exercise similar to that experienced by a hooked fish struggling during an angling event, each fish was manually chased around the tank by hand for 120 s (cf. Ferguson & Tufts 1992; Cooke *et al.* 2001). Fish were then randomly assigned to air exposure treatments of 0, 60, 120 or 240 s (Table 1). The 0-s air exposure treatment simulated hook removal in the water. Fish in the other three treatments were held horizontally by hand (one hand holding the mouth, the other gently supporting the ventral body surface, Cooke *et al.* 2001). The air exposure durations chosen for this experiment were intended to cover the range typical of angling conditions (Cooke *et al.* 2001, 2002b; Graeb, Shepherd, Willis & Sorensen 2005). Each fish was weighed (±1 g) and measured (total length to the nearest mm). The fish that were only exhaustively exercised with zero air exposure were measured under water and were weighed by placing each fish in a

Table 1. Overview of experimental protocol applied to four treatments of pikeperch retained in two ponds. Total length, body mass and condition factor are the initial conditions. *n* is the number of fish

	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Statistics
Exhaustive exercise (s)	120	120	120	120	
Air exposure time (s)	0	60	120	240	
Initial status pond 1					
n	14	15	14	13	
Total length (mm, mean ± SE)	308 ± 10	311 ± 11	325 ± 11	310 ± 10	$F = 0.517$; d.f. = 3,52; $P = 0.672$
Body mass (g, mean ± SE)	224 ± 21	216 ± 23	268 ± 34	232 ± 26	$F = 0.78$; d.f. = 3,52; $P = 0.512$
Condition factor (mean ± SE)	1.00 ± 0.03	0.95 ± 0.02	1.01 ± 0.02	1.04 ± 0.03	$F = 1.88$; d.f. = 3,52; $P = 0.145$
Initial status pond 2					
n	13	14	12	12	
Total length (mm, mean ± SE)	305 ± 11	315 ± 15	331 ± 11	335 ± 10	$F = 1.78$; d.f. = 3,47; $P = 0.293$
Body mass (g, mean ± SE)	216 ± 24	260 ± 43	273 ± 27	283 ± 27	$F = 0.85$; d.f. = 3,47; $P = 0.473$
Condition factor (mean ± SE)	1.02 ± 0.02	1.03 ± 0.03	1.00 ± 0.04	0.99 ± 0.02	$F = 0.40$; d.f. = 3,47; $P = 0.752$

water-filled bucket of appropriate size. These fish experienced air exposure only while being transferred from the fibreglass tank onto the calibrated scale (ca. 5 s). Total length, weight and condition did not differ among fish assigned to the different treatments (Table 1).

Post-angling monitoring

After simulated angling, fish were randomly stocked into one of two adjacent earthern ponds (10-m long × 3.5-m wide × 1-m deep; stocking density of 0.5 g L^{-1}) to measure growth and survival. Ponds were filled with the same water supply as the raceway and stocked with suitable-size prey fish (same species as above) a week before the angling simulation took place. Each pond was covered by a net (mesh size 150 mm) to minimise predation by birds or mammals.

Each morning, mortality of pikeperch was assessed visually by inspecting the bottom of the relatively clear pond. Dead fish were removed and identified using anchor tags. Water temperature, dissolved oxygen and pH were assessed at midday. Average water temperature ±SD was 9.3 ± 2.0 and 9.7 ± 1.9 °C, average dissolved oxygen was 9.6 ± 0.9 and 9.7 ± 0.8 mg L^{-1} and average pH was 8.1 ± 0.3 and 8.1 ± 0.3 in the two ponds and did not differ significantly between ponds (Mann–Whitney *U*-tests, $P > 0.05$ in all cases). After 40 days the ponds were drained and the remaining fish were counted, identified, measured and weighed. Fish found dead at the bottom were considered post-release mortality. Those fish not recovered after pond drainage were deleted from further analysis because their fate was uncertain.

Data analysis and statistics

Treatment-specific mortality was assessed by relating the number of dead and missing fish combined to the number of dead fish to the number of fish initially stocked minus missing fish in each pond. To assess qualitatively the potential pond-by-pond effects, treatment mortality was analysed separately per pond. Differences in mortality among air exposure treatments were assessed by chi-squared tests.

The specific growth rate (G, % day^{-1}) was estimated for those fish alive at the end of the experiment to assess growth performance using the following equation:

$$G = \frac{\ln W_2 - \ln W_1}{T_2 - T_1} \times 100$$

where W_2 and W_1 are the final and initial live body masses (g), and T_2–T_1 is the duration of the monitoring period (=40 days) (Bagenal & Tesch 1978).

A standardised condition factor (K_s) was calculated by first estimating a weight–length relationship $W = aL^b$ (L is total length in mm) using the initial weight and length data for the whole sample ($n = 144$) and a and b being the parameters to be estimated. For each fish, the expected standard weight W_s at length L was then calculated to estimate the standard condition factor K_s at length as W_s/L^3. The true condition of each fish was then expressed as a quotient as $K = (W/L^3)/K_s$. Values above one indicate that a fish has a higher condition K compared with the standard fish of the same length; values below one indicate lower condition than the standard.

Differences in G among air-exposure treatments for each pond separately were assessed by a one-way analysis of variance (ANOVA) and a Tukey *post hoc* test at $P < 0.05$. The body mass, total length and K at the time of stocking into the monitoring ponds of the fish that survived the experimental treatments vs those that died were compared by *t*-tests for each pond separately. Tests for homogeneity of variances and normal distributions were conducted to test for assumptions of the parametric statistical tests used (*t*-tests, ANOVA). All data were normally distributed (Kolmogorov–Smirnov test, $P > 0.05$) and variances were homogenous (Levene's test, $P > 0.05$), and transformations of data were therefore not needed. All statistical tests were conducted using SPSS® 12.0.

Results

All fish found dead in the ponds ($n = 15$ and 9) died within the first 3 days after release. Four fish were missing when the ponds were drained; these fish were excluded from analyses. Mortality of pikeperch ranged between 8% and 47% among air exposure treatments (Table 2). Fish exposed to air after simulated angling had higher mortality than fish with no air exposure in both ponds, but mortality did not differ significantly among treatments. Fish in all air-exposure treatments exhibited, on an average, positive growth. Growth was highly variable and not significantly different among treatments.

Fish that died after the simulated angling experience were significantly smaller in length and weight than the fish that survived the angling simulation in one of the two ponds (Table 3). There were, however, no significant differences in condition factor between dead fish and those that survived the angling simulation.

Table 2. Post-release mortality and growth of pikeperch subjected to different air exposure durations and retained in two ponds. The specific growth rate (SGR) was calculated only for those fish surviving the monitoring period. Sample size is given in parentheses

	Air exposure				
	0 s	60 s	120 s	240 s	Statistic
Pond 1					
Mortality (%)	7.7 (13)	46.7 (15)	21.4 (14)	33.3 (12)	$\chi^2 = 5.74$; d.f. = 3; $P = 0.125$
SGR (% day^{-1}, mean ± SE)	0.12 ± 0.11 (12)	0.30 ± 0.10 (8)	0.05 ± 0.09 (11)	0.18 ± 0.08 (8)	$F = 1.09$; d.f. = 3,35; $P = 0.363$
Pond 2					
Mortality (%)	7.7 (13)	23.1 (13)	9.1 (11)	33.3 (12)	$\chi^2 = 3.60$; d.f. = 3; $P = 0.307$
SGR (% day^{-1}, mean ± SE)	0.11 ± 0.07 (12)	0.06 ± 0.05 (10)	0.13 ± 0.12 (10)	0.12 ± 0.10 (8)	$F = 0.53$; d.f. = 3,36; $P = 0.667$

Table 3. Total length, body mass and condition at the time of stocking of dying and surviving pikeperch in two ponds. Sample size is given in parentheses

	Dead fish	Survivors	Statistic
Pond 1			
Total length (mm, mean ± SE)	306 ± 9.4 (15)	315 ± 6.4 (39)	$t = 0.79$; d.f. = 52; $P = 0.433$
Body mass (g, mean ± SE)	213 ± 21 (15)	240 ± 16 (39)	$t = 0.89$; d.f. = 52; $P = 0.376$
Condition factor (mean ± SE)	0.99 ± 0.03 (15)	1.00 ± 0.02 (39)	$t = 0.22$; d.f. = 52; $P = 0.827$
Pond 2			
Total length (mm, mean ± SE)	282 ± 12 (9)	328 ± 7 (40)	$t = 3.02$; d.f. = 47; $P = 0.004$
Body mass (g, mean ± SE)	165 ± 24 (9)	275 ± 17 (40)	$t = 2.78$; d.f. = 47; $P = 0.008$
Condition factor (mean ± SE)	0.99 ± 0.04 (9)	1.00 ± 0.03 (40)	$t = 0.45$; d.f. = 47; $P = 0.654$

Discussion

This study did not detect a statistically significant difference in mortality among different durations of air exposure. However, mortality was lowest in both ponds for fish with no air exposure after simulated capture and before release, which suggested that air exposure adversely affected survival. Previous research in the congeneric walleye, *Sander vitreum* (Mitchill), showed that exhaustive exercise and air exposure can lead to various physiological and cardiac changes typical of elevated activity and metabolism (Killen, Suski, Morrissey, Dyment, Furimsky & Tufts 2003; Killen, Suski, Cooke, Philipp & Tufts 2006). Such physiological disturbances and associated energy depletion may cause mortality, presumably because of the magnitude of physiological disturbance in the muscle due to exhaustive, anaerobic exercise (e.g. intracellular acidosis; Wood, Turner & Graham 1983), and the collapse and adhesion of gill filaments due to air exposure (Ferguson & Tufts 1992). The mortality observed in air-exposed pikeperch in the present experiment may result, at least partially, from exceeding physiological tolerance levels. Fisheries managers, aquaculturists and anglers have noted that pikeperch is more sensitive to external stressors than other percid species (Schlumberger & Proteau 1996), possibly because of different capacities of fish from the genus *Sander* to tolerate hypoxia (Killen *et al.* 2003). Results of this study also suggested that mortality in response to air exposure is inversely related to size of pikeperch. However, data analysis was constrained by limited replication. Further study with expanded trials or alternative mortality assessment protocols is recommended to more fully evaluate the effect of air exposure on caught-and-released sublegal pikeperch.

The present study showed that air-exposed pikeperch did not experience reduced growth. This result agrees with results obtained for largemouth bass, *Micropterus salmoides* (Lacepède), by Quinn (1989) and Pope & Wilde (2004) and for bream, *Abramis brama* (L.) by Raat, Klein Breteler & Jansen (1997). However, the results of the present study contradict those of Clapp & Clark's (1989) study in smallmouth bass, *Micropterus dolomieu* Lacepède, and Diodati & Richards' (1996) work on striped bass, *Morone saxatilis* (Walbaum). Clapp & Clark (1989) reported that growth of individual smallmouth bass was inversely related to the number of times they were captured. Possibly, growth of pikeperch may be affected with multiple captures.

One factor that might have influenced the results of the present study is that hatchery-reared fish were used. Hatchery-reared fish are rarely required to swim at high speeds or perform bouts of anaerobic activity (Booth, Kieffer, Davidson, Bielak & Tufts 1995). Although no differences in physiological responses to C&R stress were found between wild- and hatchery-reared red drum, *Sciaenops occellatus* (L.) (Gallmann, Isely, Tomasso & Smith 1999), other workers found significant differences between hatchery- and wild-reared salmonids in their physiological response to hooking (Wydoski, Wedemeyer & Nelson 1976; Tufts, Tang, Tufts & Boutilier 1991). The exhaustive exercise exerted in the present experimental protocol might have constituted a deviation from the usual demands the experimental fish have been exposed to during their life in the hatchery. Care is therefore advocated to transfer uncritically the results of this study to wild fish. Moreover, the mortality estimates of the present study were not corrected against a potential background mortality of reference fish. The values presented here are, therefore, considered minimal estimates of survival of pikeperch subjected to C&R and air exposure.

In line with other research on freshwater fish species (e.g. Cooke & Suski 2005; Schreer *et al.* 2005), our findings suggest that anglers should avoid exposing undersized pikeperch to air when handling the fish. The first strategy would be to increase bait sizes or increase and modify terminal gear (e.g. hook sizes) to increase the probability of hooking larger fish (cf. Wilde, Pope & Durham 2003). Sublegal fish that are hooked should be unhooked in the water. If anglers need to check for length of the fish, a larger handling net should be used so that measurements can be taken in the water. Clearly, appropriate use of pliers or similar devices can help in rapid handling of the fish, thus minimising air exposure of sublegal pikeperch.

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